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1 Attorney Docket No. 78675

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3 ACOUSTIC SOUND SPEED PROFILING SYSTEM

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5 STATEMENT OF GOVERNMENT INTEREST

6 The invention described herein may be manufactured and used
7 by or for the Government of the United States of America for
8 Governmental purposes without the payment of any royalties
9 thereon or therefor.

10
11 BACKGROUND OF THE INVENTION

12 (1) Field of the Invention

13 The invention relates to the field of sonar measuring
14 devices and in particular to devices for measuring the speed of
15 sound in water.

16 (2) Description of the Prior Art

17 The use of sonar systems continues to broaden, covering
18 depth finding, target detection, location, ranging and all
19 traditional uses. New uses include the aiming of small
20 underwater projectiles against relatively small incoming threats,
21 e.g., underwater bullets fired at incoming torpedoes. Each of
22 these new uses requires increased resolution, speed, and accuracy
23 from a sonar tracking or aiming system. In order to provide this
24 increased resolution, speed and accuracy, it is important to

1 minimize errors in the measurement of signals from these threats.
2 Significant errors can result from inaccurate sound velocity
3 profiles in the water column. Currently the U.S. Navy uses
4 expendable bathythermometric (XBT) devices to measure the
5 temperature profile of the water column. From this measured
6 temperature profile, the sound speed profile is calculated and
7 used to improve sonar performance. These XBT devices have a
8 number of drawbacks including the inability to measure the sound
9 speed directly, the lack of continuous measurement, the
10 requirement for repeated deployment intervals during a day, and
11 the considerable debris generated with intensive use. With the
12 rapidly changing conditions found in shallow, littoral water
13 environments (environments having fresh water influxes), the need
14 for a realtime continuous sound speed measurement is crucial to
15 maintain optimum sonar performance. In these types of
16 environments, XBT's are least effective as not only the water
17 temperature is changing rapidly, but the salinity is also
18 changing. Since XBT's measure the speed of sound indirectly
19 (based on temperature), significant inaccuracies can result.
20 Additionally, the rapidly changing conditions require even
21 greater numbers of XBT deployments.

22 Other examples of prior art devices for measuring sound
23 speed include direct measurement devices for static, non-moving
24 systems and indirect, calculated determinations for moving

1 systems. For example, U.S. Patent No. 4,558,437 to Meeder et al.
2 disclosed a static device having an emitter at the seafloor with
3 a receive sensor located at the boat. Meeder et al. disclose a
4 static system which measures sound pressure levels in ocean
5 sediment, but cannot be adapted to measurement throughout the
6 water column, nor to moving systems. Typically, moving systems
7 depend on calculation and/or indirect measurements. U.S. Patent
8 No. 5,608,689 to Capell, Sr. is an example disclosing a moving
9 system which calculates the speed of sound based on transmitting
10 and receiving at one location (on the ship). The necessary
11 calculations, based on multiple pulses, require a precise
12 knowledge of transmission and reception angles.

13 What is needed is a realtime means for directly measuring
14 the speed of sound profile throughout a water column. Additional
15 measurement from a moving platform is required and measurement
16 using a simple omni-directional sound source is preferable.

18 SUMMARY OF THE INVENTION

19 It is an object of the invention to provide an aquatic sound
20 speed profiling system adapted to operate in freshwater, brackish
21 water and seawater.

22 It is another object of the invention to provide a sound
23 speed profiling system adapted to operate at varying water
24 temperatures.

1 It is yet another object of the invention to provide a sound
2 speed profiling system using direct measurement of the speed of
3 sound.

4 It is still another object of the invention to provide a
5 sound speed profiling system having realtime speed measurements.

6 Accordingly, the invention is an acoustic sound speed
7 profiling system comprising a high-frequency acoustic source and
8 a series of receive sensors deployed through a water column. The
9 high-frequency acoustic source is mounted in the front end of a
10 passive, towed array. The high-frequency source has a frequency
11 which may be outside the bandwidth of the acoustic aperture of
12 the towed array or threat receive arrays. The series of receive
13 sensors are located at intervals along the array tow cable
14 leading up to the towing ship. These sensors may be traditional
15 hydrophones or thin film hydrophone membranes, such as
16 polyvinylidene fluoride (PVDF). During operation of the system,
17 the source transmits high frequency sound, which is received by
18 each sensor along the tow cable of the towed array. Calculation
19 of the speed of sound is determined from the position of the tow
20 cable and the time-of-arrival of acoustic signals at each sensor.

21 There is no interference with the normal operation of the
22 passive towed array.

1 BRIEF DESCRIPTION OF THE DRAWINGS

2 The foregoing objects and other advantages of the present
3 invention will be more fully understood from the following
4 detailed description and reference to the appended drawings
5 wherein corresponding reference characters indicate corresponding
6 parts throughout the several views of the drawings and wherein:

7 FIG. 1 is a side view sketch showing the sound speed
8 profiling system installed on a passive towed sonar array; and

9 FIG. 2 is a schematic view of the sound speed profiling
10 system.

11
12 DESCRIPTION OF THE PREFERRED EMBODIMENTS

13 Referring now to FIG. 1, the sound speed profiling system of
14 the present invention, designated generally by the reference
15 numeral 10, is shown with its major components. The sound speed
16 profiling system 10 comprises a high frequency, omni-
17 directional, acoustic source 12, mounted in the front of a
18 passive towed sonar array 14 (an existing array serving as a
19 mounting platform). The acoustic source 12 has a transmitting
20 frequency which may be outside the bandwidth of the acoustic
21 aperture of the towed array 14. This acoustic source 12 may be
22 back-fit into an existing towed array 14 that can fulfill the
23 power requirements of the acoustic source, or may be designed
24 into a new development towed array. The sonar array 14 is towed

1 from a vessel 16 with an electro-optical-mechanical tow cable 18
2 having an outer plastic jacket. The tow cable 18 has internal
3 wiring and power cables (not shown) and serves as a sensor
4 support having a plurality of sensors 20 embedded in the outer
5 jacket of the tow cable 18. These sensors 20 measure the arrival
6 times of the acoustic signals 22 transmitted from the acoustic
7 source 12 located on the towed array 14. By knowing the time at
8 which the signals 22 are transmitted from the array 14, the time
9 that the signals 22 arrive at each of the sensors 20 on the cable
10 18, and the position of the tow cable, a plot of sound speed
11 verses depth can be acquired.

12 Referring now to FIG. 2, a schematic diagram shows the
13 operation of the sound speed profiling system 10. The acoustic
14 source 12 is shown located on an existing passive towed sonar
15 array 14. The tow cable 18 is a typical electro-optical,
16 mechanical cable modified to attach sensors 20 at intervals along
17 the cable. These sensors may be embedded in the jacket of the
18 tow cable and may comprise optical fibers configured to detect
19 sonar signals (such as well known Bragg grating sensors),
20 traditional ceramic hydrophone elements, or thin-film hydrophone
21 membranes formed with piezo-electric polymers such as
22 polyvinylidene fluoride polymer films (PVDF). PVDF provides
23 additional benefits as it can be manufactured in very thin films
24 which could be embedded into the tow cable jacket without

1 affecting the thickness or outer diameter of the tow cable
2 jacket. The tow cable jacket also contains a plurality of
3 electrical conductors (not shown) that transmit the signals from
4 the sensors to the towing vessel (not shown in this figure).
5 Onboard the towing vessel, a microprocessor and controller unit
6 26 operates the sound speed profiling system. The microprocessor
7 and controller unit 26 is connected to the tow cable 18, and to
8 the acoustic source 12 and sensors 20, through the cable handling
9 system 24. Ship's power is connected to both the microprocessor
10 and controller unit 26 and the tow cable 18 through the cable
11 handler 24 as shown by connections 28. The tow cable 18 has
12 internal wiring to actuate the acoustic source 12 and for
13 transfer of signals received by sensors 20 back to the
14 microprocessor and controller unit 26. A connection 30 is
15 provided to transfer the water column sound speed profile data to
16 the ship's combat system. This data is used to optimize sonar
17 system performance including the depth of the towed
18 array 14.

19 The features and advantages of the system are numerous. The
20 system has an active acoustic source, which can be easily mounted
21 into the front of a towed array using the power and signal
22 electrical conductors already existing. Modifications to the
23 hull of the ship are not required. Thin PVDF hydrophones can be
24 built into the jacket of the tow cable with no impact to the

1 electrical, optical or mechanical performance. As arrays are
2 typically towed from Navy combatants, this sound speed profiling
3 system requires only a modification to an existing system, and
4 does not require an entire system development. Unlike the
5 present alternative (XBT), which provides only the temperature
6 profile, the sound speed profiling system directly, rapidly and
7 continuously measures changes in the sound speed. This direct
8 measurement allows accurate results even in shallow and littoral
9 waters in which both temperature and salinity may be rapidly
10 changing. Further, the sound speed profiling system allows the
11 use of an omni-directional sound source, without the necessity of
12 controlling or even knowing source-sensor angular relationship.

13 It will be understood that many additional changes in the
14 details, materials, steps and arrangement of parts, which have
15 been herein described and illustrated in order to explain the
16 nature of the invention, may be made by those skilled in the art
17 within the principle and scope of the invention,

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3 ACOUSTIC SOUND SPEED PROFILING SYSTEM

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5 ABSTRACT OF THE DISCLOSURE

6 An acoustic sound speed profiling system is provided. The
7 system includes a sound emitter and a series of sensors or
8 hydrophones spaced vertically in a water column. The sound
9 emitter is a high-frequency sound source adapted for mounting on
10 the front end of a passive, towed sonar array. The sound source
11 has a frequency which may be outside the acoustic aperture of the
12 towed array. The series of sensors are located at intervals
13 along and embedded within the array tow cable. The sensors are
14 conventional hydrophones or thin-film hydrophone membranes.
15 During operation of the system, the source transmits high
16 frequency sound, which is received by each sensor along the tow
17 cable of the towed array. Calculation of the speed of sound is
18 determined from the position of the tow cable and the time-of-
19 arrival of acoustic signals at each sensor. There is no
20 interference with the normal operation of the passive towed
21 array.

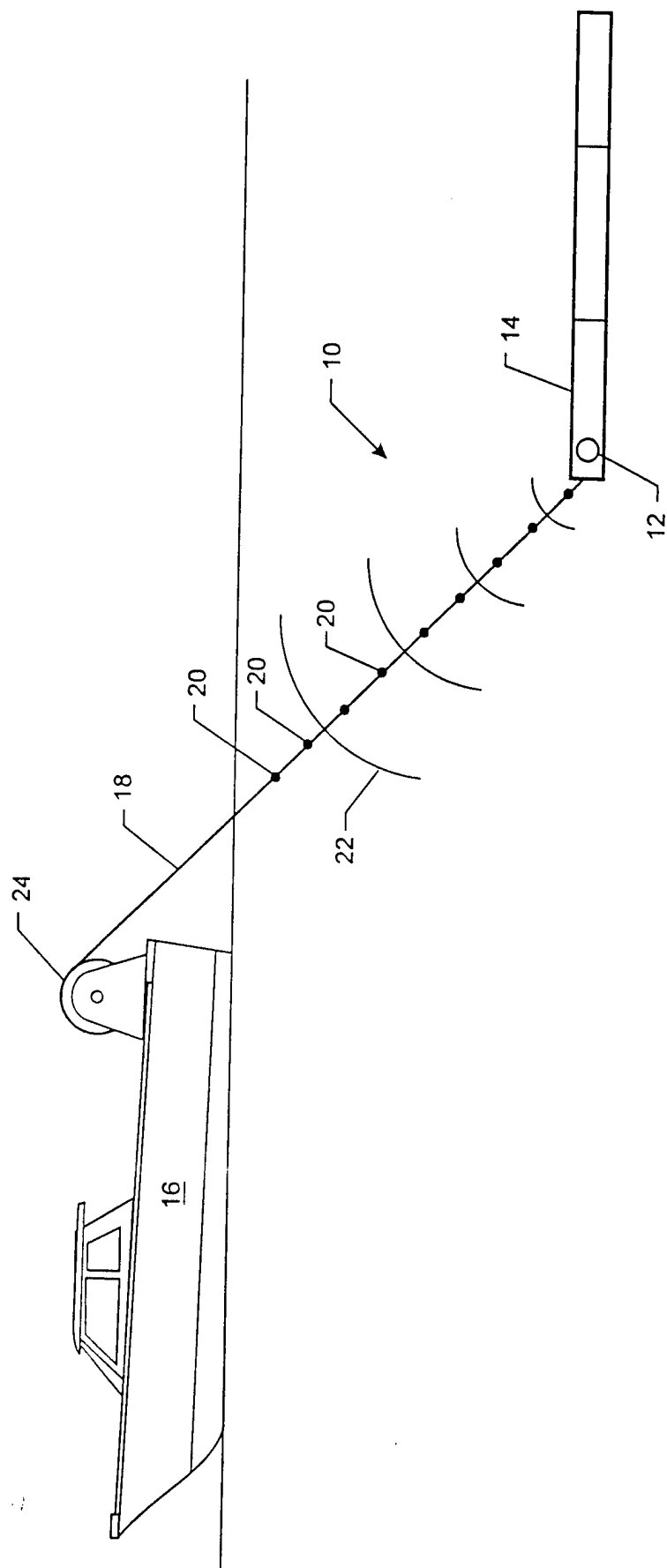


FIG. 1

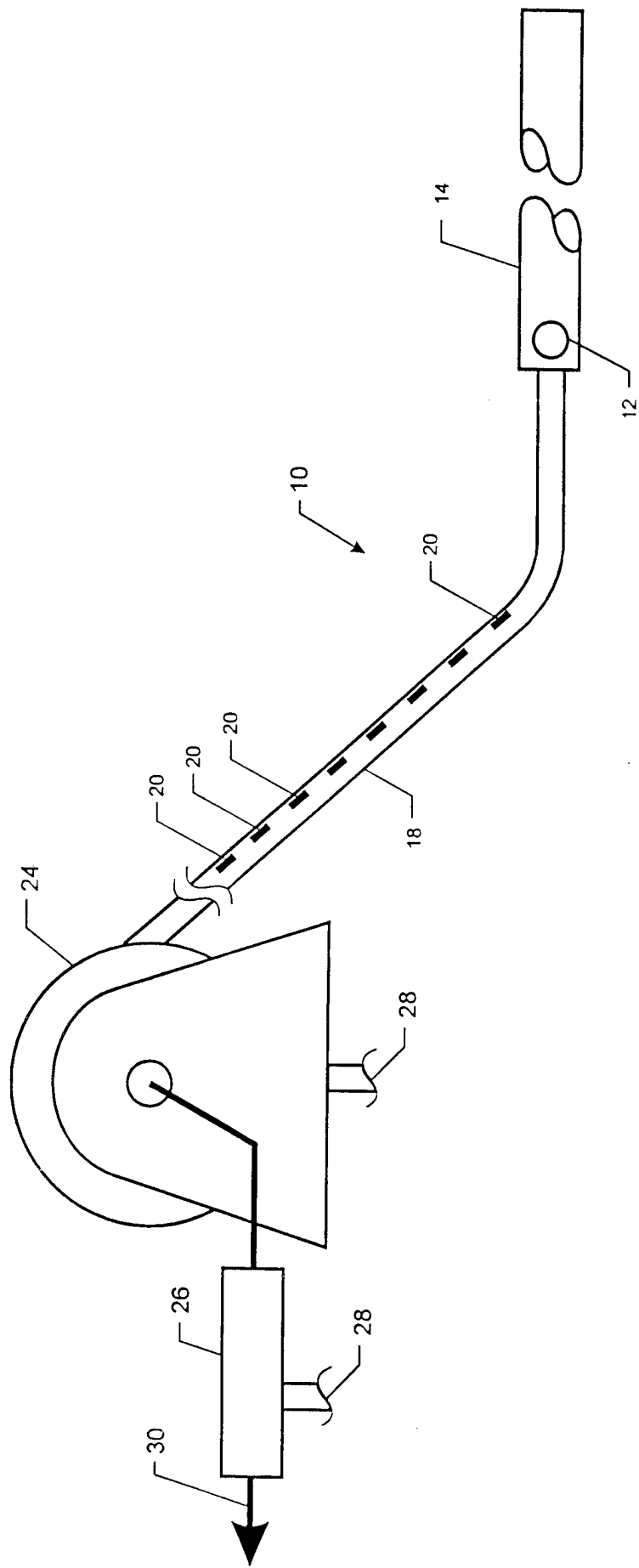


FIG. 2